FIG. 1

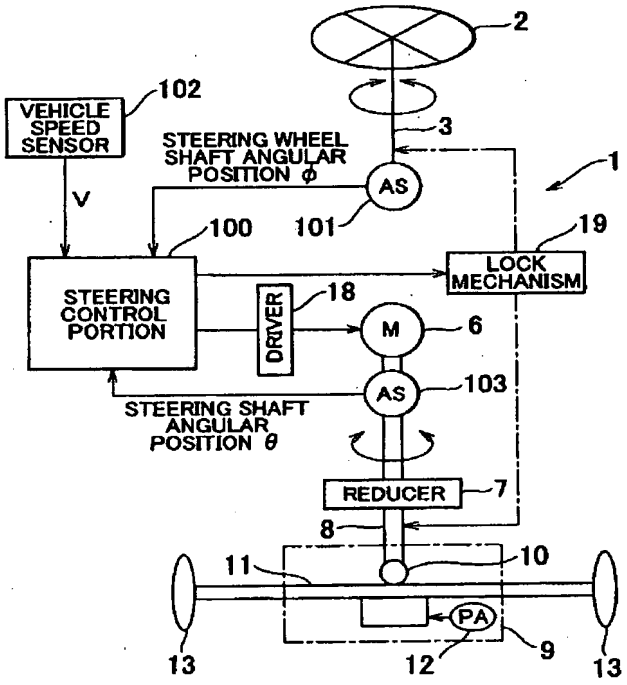
2
3
1
VEHICLE SPEED SENSOR
102
STEERING WHEEL SHAFT ANGULAR POSITION φ
AS
101
V
100
19
LOCK MECHANISM
STEERING CONTROL PORTION
DRIVER
18
M
6
AS
103
STEERING SHAFT ANGULAR POSITION θ
REDUCER
7
8
11
10
PA
9
13
12
13

FIG. 2

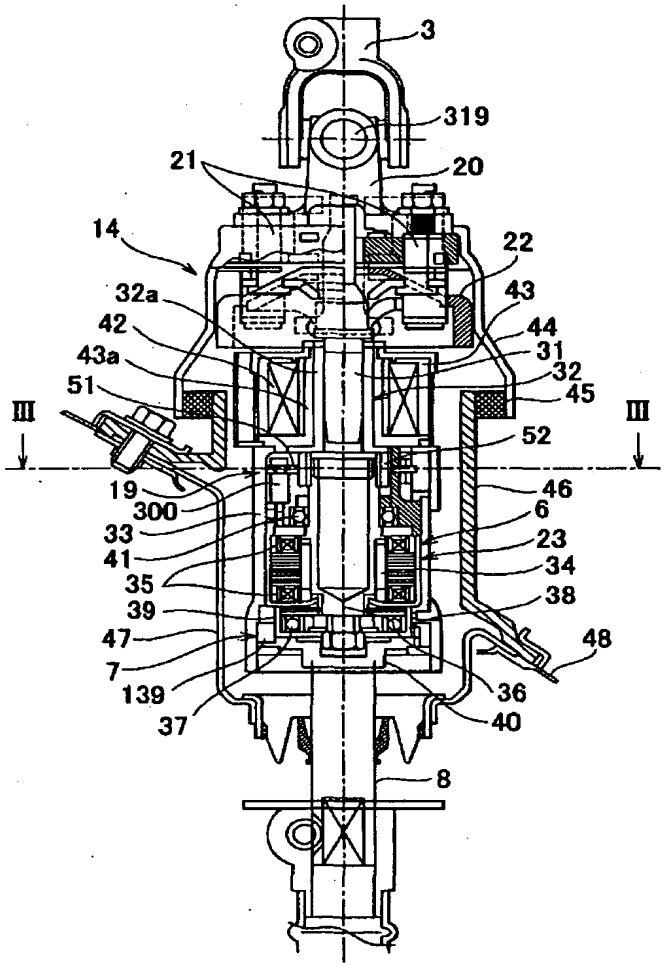
3
319
21
20
14
22
32a
43
42
44
43a
31
32
51
45
III
III
52
19
46
300
6
33
23
41
34
35
38
39
47
48
7
36
139
37
40
8

FIG. 3

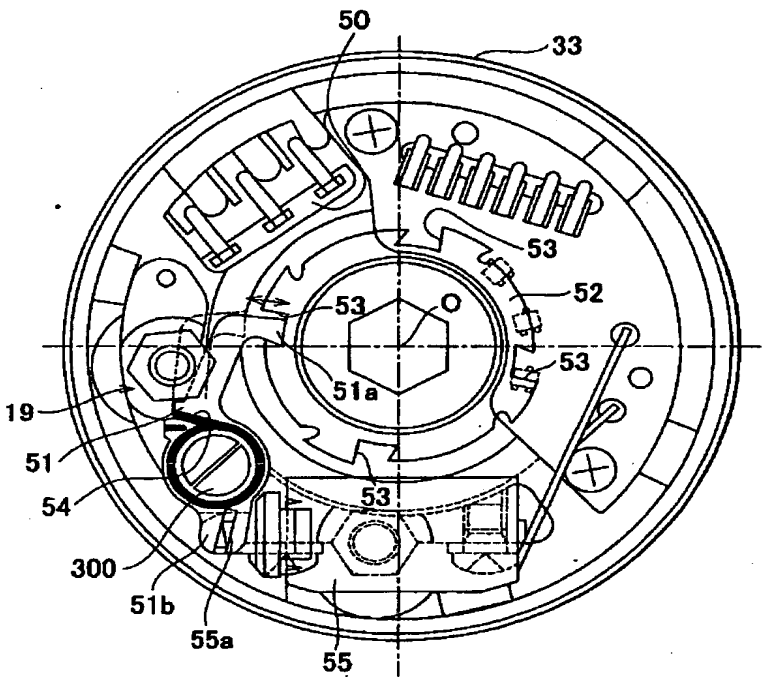

FIG. 4

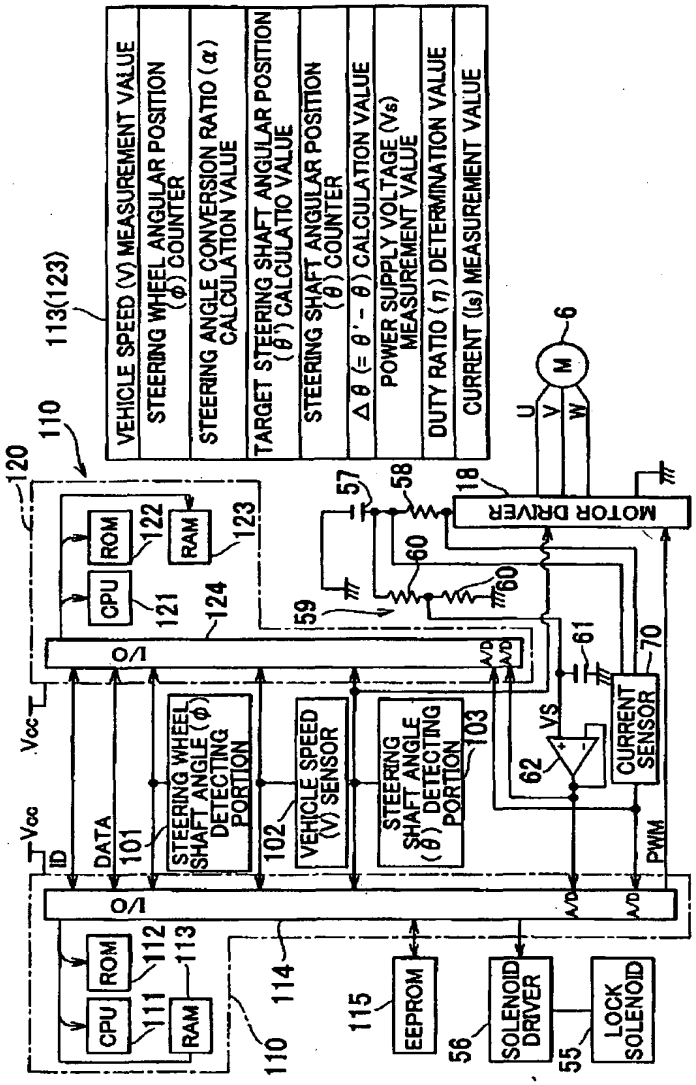
VEHICLE SPEED (V) MEASUREMENT VALUE
STEERING WHEEL ANGULAR POSITION (φ) COUNTER
STEERING ANGLE CONVERSION RATIO (α) CALCULATION VALUE
TARGET STEERING SHAFT ANGULAR POSITION (θ') CALCULATIO VALUE
STEERING SHAFT ANGULAR POSITION (θ) COUNTER
Δθ (= θ' − θ) CALCULATION VALUE
POWER SUPPLY VOLTAGE (Vs) MEASUREMENT VALUE
DUTY RATIO (η) DETERMINATION VALUE
CURRENT (Is) MEASUREMENT VALUE
113(123)
110
120
ROM
CPU
RAM
122
121
123
124
I/O
A/D
Vcc
ID
DATA
101
STEERING WHEEL SHAFT ANGLE (φ) DETECTING PORTION
102
VEHICLE SPEED (V) SENSOR
STEERING SHAFT ANGLE (θ) DETECTING PORTION
103
PWM
112
111
113
114
115
EEPROM
56
SOLENOID DRIVER
55
LOCK SOLENOID
57
58
18
MOTOR DRIVER
60
59
61
70
CURRENT SENSOR
VS
62
U
V
W
M
6

FIG. 5

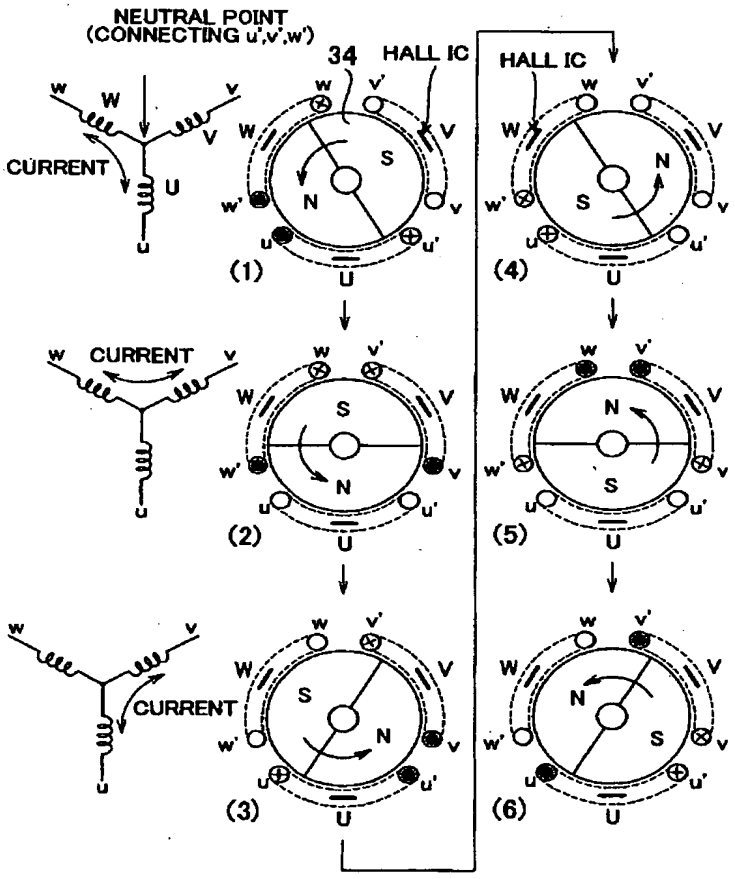
NEUTRAL POINT
(CONNECTING u',v',w')
34
HALL IC
HALL IC
CURRENT
CURRENT
CURRENT
(1)
(2)
(3)
(4)
(5)
(6)
U
V
W
u
v
w
u'
v'
w'
N
S

FIG. 6

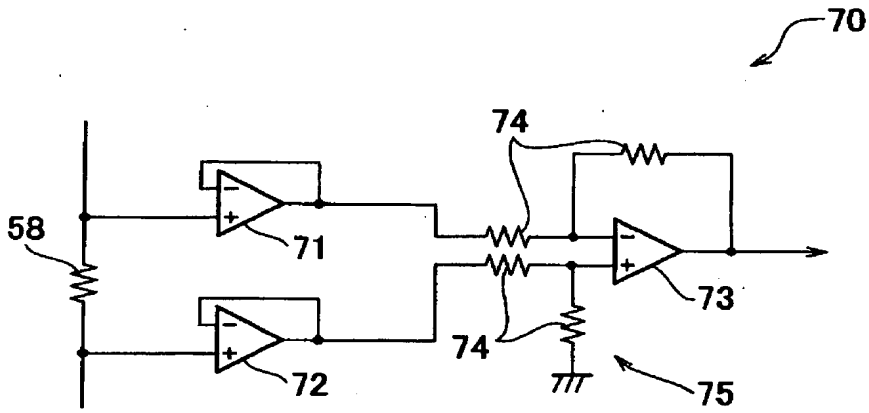

FIG. 7

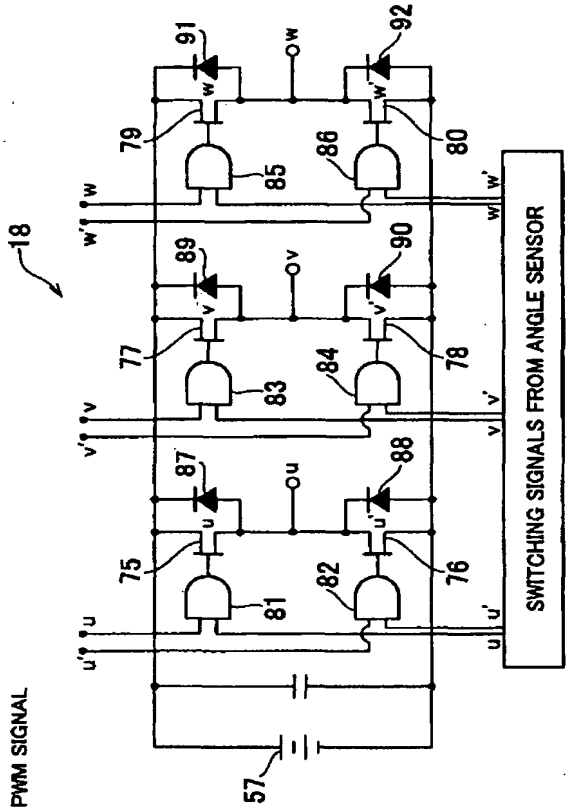
18
PWM SIGNAL
57
91
92
79
80
85
86
89
90
77
78
83
84
87
88
75
76
81
82
w
v
u
SWITCHING SIGNALS FROM ANGLE SENSOR

FIG. 8A

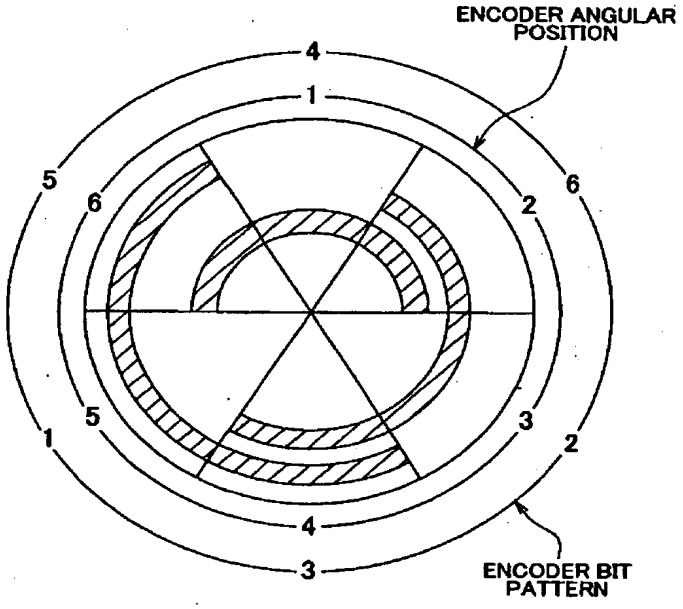
ENCODER ANGULAR POSITION
4
1
5
6
2
6
5
3
1
2
4
3
ENCODER BIT PATTERN

FIG. 8B

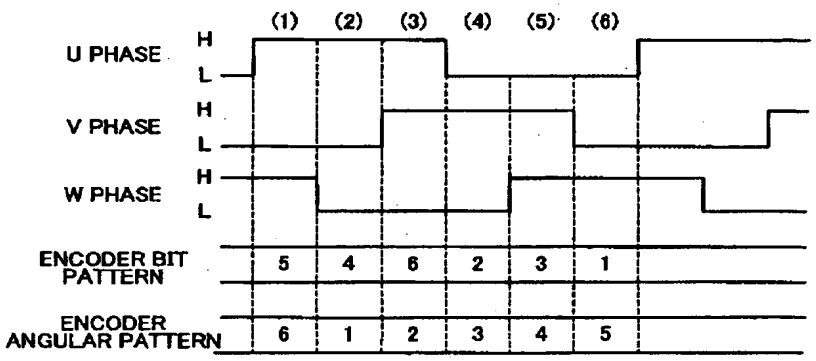
(1)
(2)
(3)
(4)
(5)
(6)
U PHASE
V PHASE
W PHASE
H
L
ENCODER BIT PATTERN
5
4
6
2
3
1
ENCODER ANGULAR PATTERN
6
1
2
3
4
5

FIG. 9

130

VEHICLE SPEED (V)	V_1	V_2	V_3	.....	V_n
STEERING ANGLE CONVERSION RATIO (α)	α_1	α_2	α_3	.....	α_n

$\alpha = \theta / \phi$

ϕ : STEERING WHEEL SHAFT ANGULAR POSITION

θ : STEERING SHAFT ANGULAR POSITION

FIG. 10

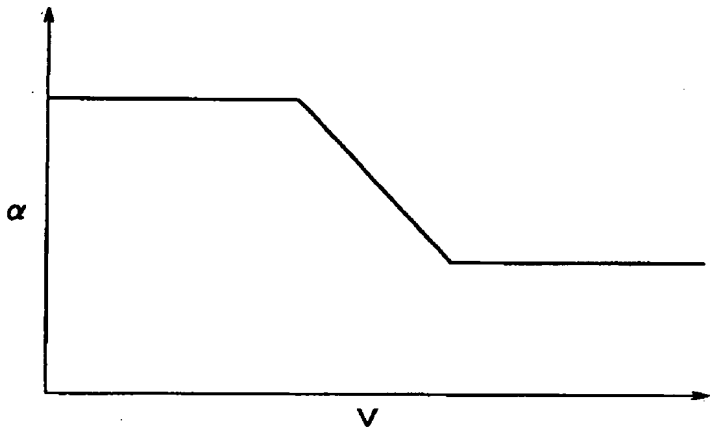

FIG. 11

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Vs / $\Delta\theta$	Vs_1	Vs_2	Vs_3	Vs_4	...	Vs_n
$\Delta\theta_1$	η_{11}	η_{12}	η_{13}	η_{14}	...	η_{1n}
$\Delta\theta_2$	η_{21}	η_{22}	η_{23}	η_{24}	...	η_{2n}
$\Delta\theta_3$	η_{31}	η_{32}	η_{33}	η_{34}	...	η_{3n}
$\Delta\theta_4$	η_{41}	η_{42}	η_{43}	η_{44}	...	η_{4n}
⋮	⋮	⋮	⋮	⋮	⋮	⋮
$\Delta\theta_m$	η_{m1}	η_{m2}	η_{m3}	η_{m4}	...	η_{mn}

η : DUTY RATIO
$\Delta\theta = \theta' - \theta$

θ' : TARGET STEERING SHAFT ANGULAR POSITION
θ : CURRENT STEERING SHAFT ANGULAR POSITION

FIG. 12

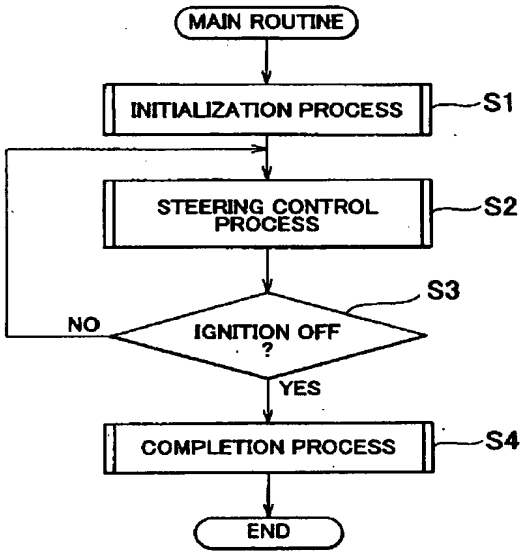

MAIN ROUTINE
INITIALIZATION PROCESS
S1
STEERING CONTROL PROCESS
S2
S3
NO
IGNITION OFF ?
YES
COMPLETION PROCESS
S4
END

FIG. 13

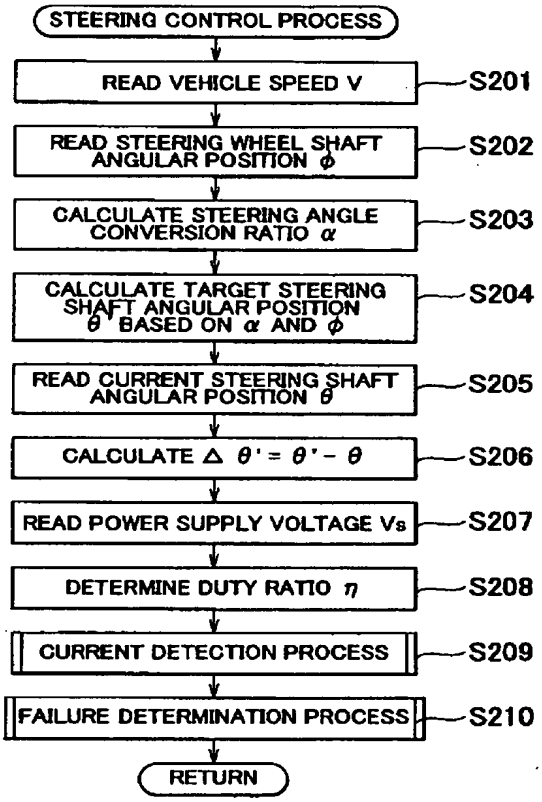

STEERING CONTROL PROCESS
READ VEHICLE SPEED V
S201
READ STEERING WHEEL SHAFT ANGULAR POSITION φ
S202
CALCULATE STEERING ANGLE CONVERSION RATIO α
S203
CALCULATE TARGET STEERING SHAFT ANGULAR POSITION θ' BASED ON α AND φ
S204
READ CURRENT STEERING SHAFT ANGULAR POSITION θ
S205
CALCULATE Δ θ' = θ' − θ
S206
READ POWER SUPPLY VOLTAGE Vs
S207
DETERMINE DUTY RATIO η
S208
CURRENT DETECTION PROCESS
S209
FAILURE DETERMINATION PROCESS
S210
RETURN

FIG. 14

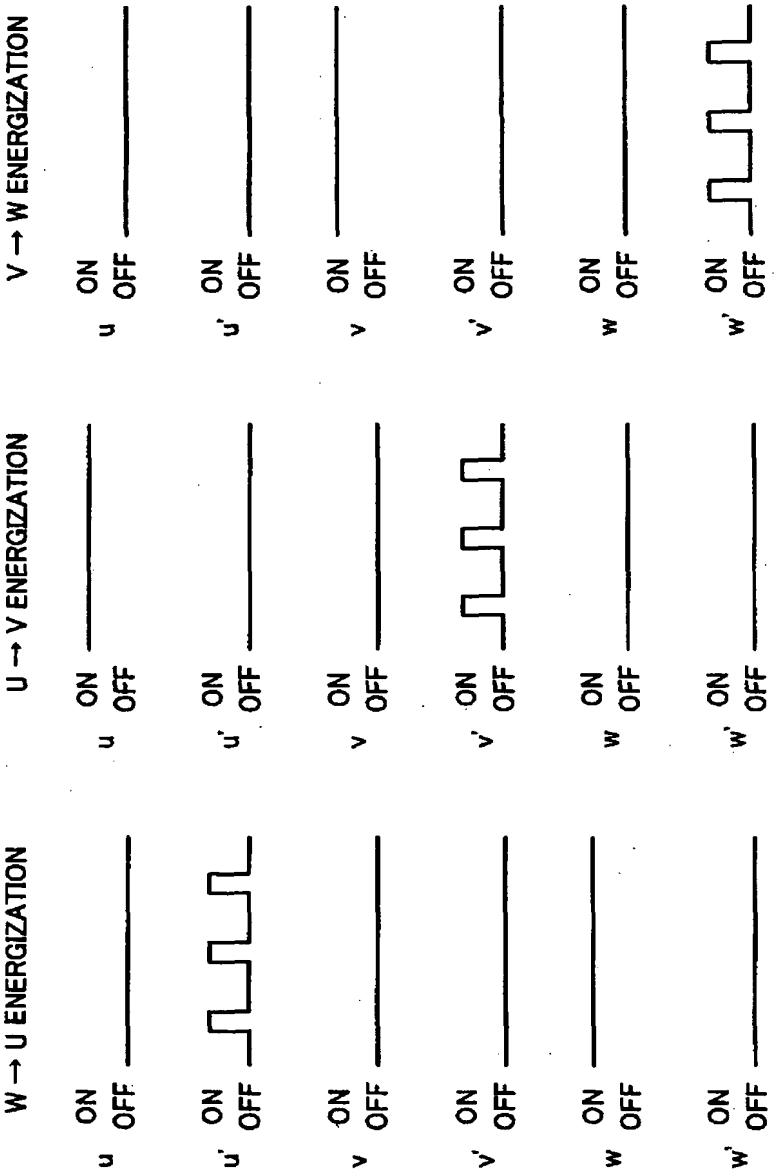

W → U ENERGIZATION
U → V ENERGIZATION
V → W ENERGIZATION
ON
OFF
u
u'
v
v'
w
w'

FIG. 15

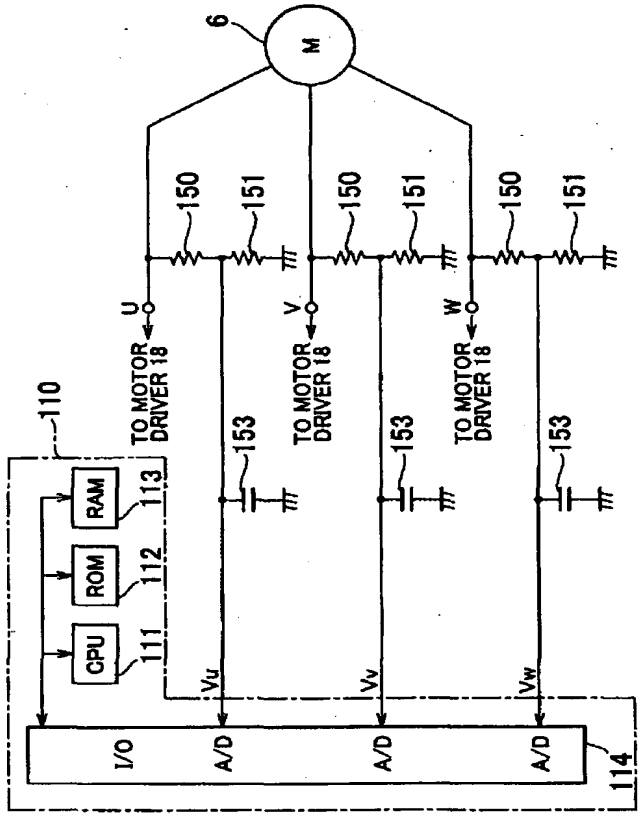

6
M
150
151
150
151
150
151
U
V
W
TO MOTOR DRIVER 18
TO MOTOR DRIVER 18
TO MOTOR DRIVER 18
153
153
153
110
RAM
113
ROM
112
CPU
111
Vu
Vv
Vw
I/O
A/D
A/D
A/D
114

FIG. 16

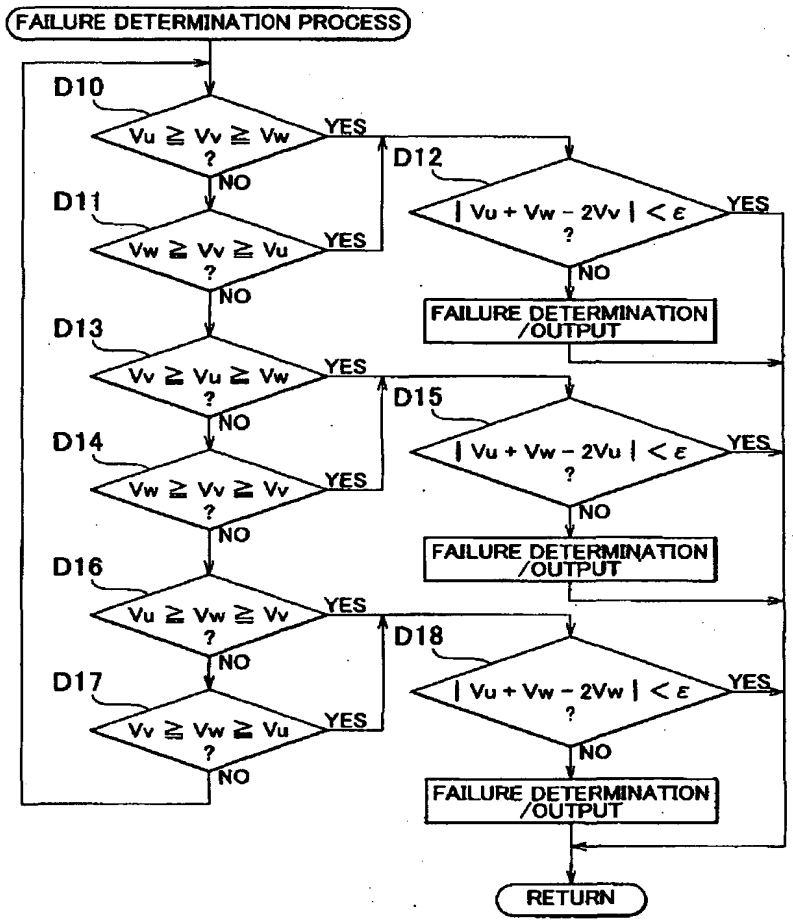
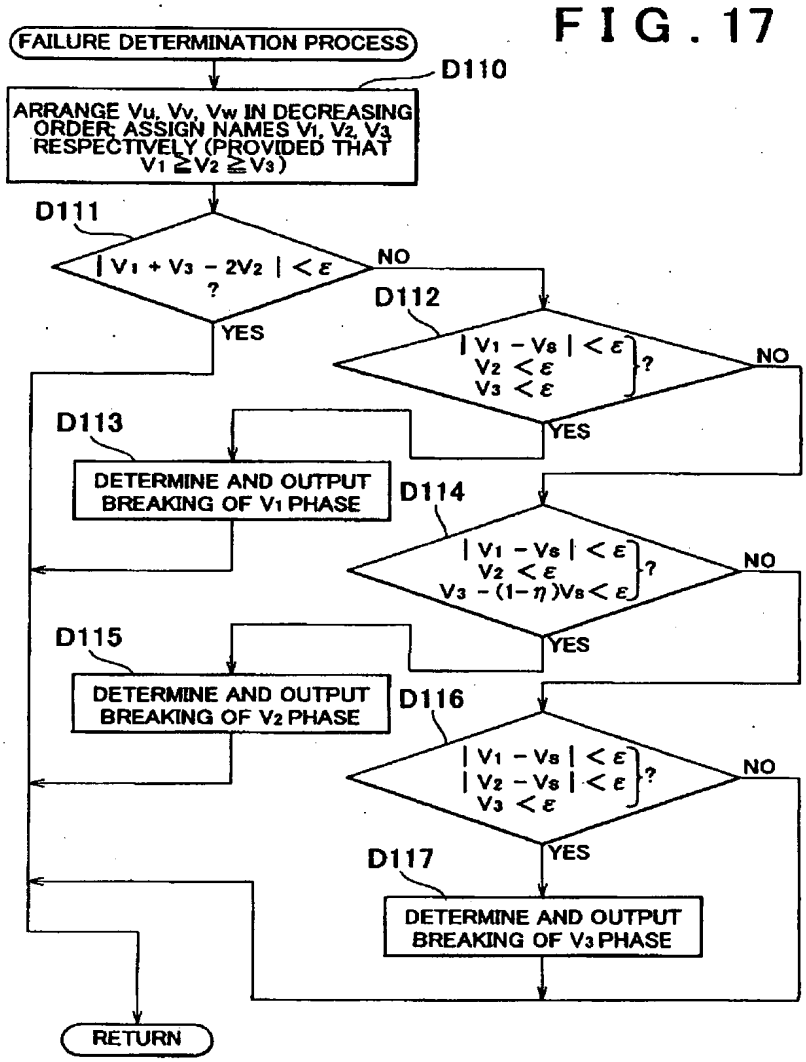

FAILURE DETERMINATION PROCESS
D10
Vu ≧ Vv ≧ Vw ?
YES
NO
D11
Vw ≧ Vv ≧ Vu ?
YES
NO
D12
| Vu + Vw − 2Vv | < ε ?
YES
NO
FAILURE DETERMINATION /OUTPUT
D13
Vv ≧ Vu ≧ Vw ?
YES
NO
D14
Vw ≧ Vv ≧ Vv ?
YES
NO
D15
| Vu + Vw − 2Vu | < ε ?
YES
NO
FAILURE DETERMINATION /OUTPUT
D16
Vu ≧ Vw ≧ Vv ?
YES
NO
D17
Vv ≧ Vw ≧ Vu ?
YES
NO
D18
| Vu + Vw − 2Vw | < ε ?
YES
NO
FAILURE DETERMINATION /OUTPUT
RETURN

FIG. 17


FAILURE DETERMINATION PROCESS
D110
ARRANGE Vu, Vv, Vw IN DECREASING ORDER; ASSIGN NAMES V1, V2, V3 RESPECTIVELY (PROVIDED THAT V1 ≧ V2 ≧ V3)
D111
| V1 + V3 − 2V2 | < ε ?
NO
YES
D112
| V1 − Vs | < ε
V2 < ε
V3 < ε
?
NO
YES
D113
DETERMINE AND OUTPUT BREAKING OF V1 PHASE
D114
| V1 − Vs | < ε
V2 < ε
V3 − (1−η)Vs < ε
?
NO
YES
D115
DETERMINE AND OUTPUT BREAKING OF V2 PHASE
D116
| V1 − Vs | < ε
| V2 − Vs | < ε
V3 < ε
?
NO
YES
D117
DETERMINE AND OUTPUT BREAKING OF V3 PHASE
RETURN